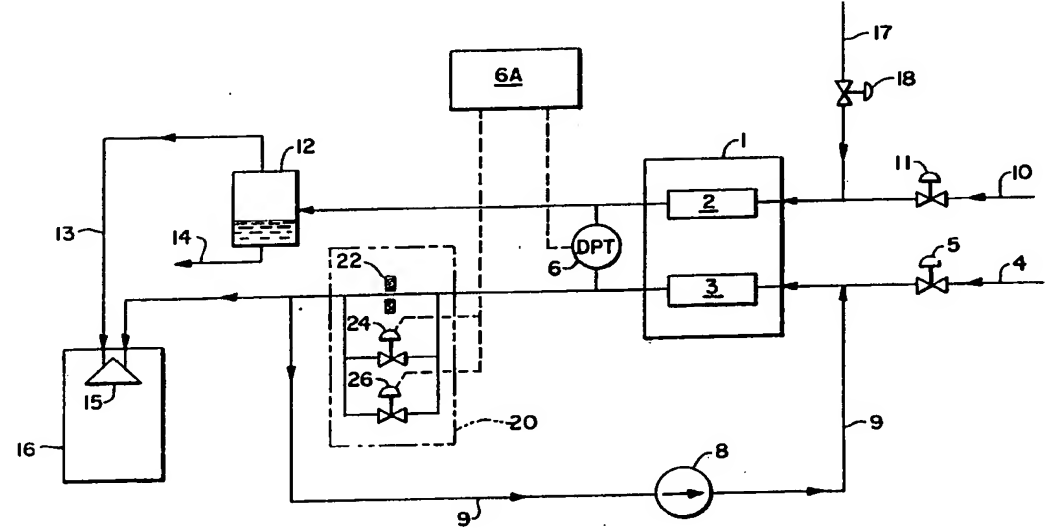




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification 5 :</b>  <b>H01M 8/04</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 91/17578</b>  <b>(43) International Publication Date:</b> 14 November 1991 (14.11.91)
<b>(21) International Application Number:</b> PCT/US91/03279 <b>(22) International Filing Date:</b> 10 May 1991 (10.05.91)  <b>(30) Priority data:</b> 521,480                      10 May 1990 (10.05.90)                      US  <b>(71) Applicant:</b> INTERNATIONAL FUEL CELLS CORPORATION [US/US]; 195 Governors Highway, South Windsor, CT 06074 (US).  <b>(72) Inventors:</b> VARTANIAN, George ; 4 Hayes Avenue, Ellington, CT 06029 (US). LANDAU, Michael, B. ; 9 Porter Drive, West Hartford, CT 06117 (US).  <b>(74) Agent:</b> KOCHEY, Edward, L., Jr.; United Technologies Corporation, Patent Department, Hartford, CT 06101 (US).		<b>(81) Designated State:</b> JP.  <b>Published</b> <i>With international search report.</i>
<b>(54) Title:</b> FUEL CELL POWER PLANT  		
<b>(57) Abstract</b>  Pressure differential (6) between cathode (2) and anode (3) is controlled by valve (24, 26) of valve complex (20). The complex (20) is located within anode recirculation loop (8, 9, 3, 20) whereby controllability is not lost with no flow through the anode. Control is thereby retained during nitrogen purging of the cathode. An orifice (22) in the valve complex (20) precludes accidental full closure of the complex, and is selected to avoid immediate damage to the fuel cell on such closure.		

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## 1

## Description

## Fuel Cell Power Plant

## Technical Field

5 This invention relates to a power plant using a fuel cell and more particularly to the fuel cell limiting the pressure difference between the anode and cathode sides of the cells.

## Background of the Invention

10 In a fuel cell, the electrolyte between the anode and cathode is formed thin normally so that an internal resistance of the cell is small.

For this reason, when a cell cross differential pressure between the anode and the cathode becomes high, fuel supplied to the anode or air supplied to the cathode passes said electrolyte while not subject to an electrochemical reaction, thus causing so-called crossover phenomena and resulting in the deterioration of cell performance or partial fracture. While the long term tolerable pressure differential is in the order of 5 cm of water, a higher differential can briefly be tolerated as a time related function. For instance, 200 cm of water may be tolerated for 1 second or 25 cm for 10 seconds.

25 A conventional fuel cell plant known in the prior is shown in Figure 3. Air from line 10 passes through flow control valve 11 to cathode 2 of fuel cell 1. Discharge from the cathode passes through separator 12

where water is removed 14. The air continues through line 13 to burner 15 of reformer 16.

Fuel from line 4 passes through flow control valve 5 to anode 3 of fuel cell 1. Residual fuel passes to burner 15 in reformer 16 for combustion. Blower 8 operates in recirculation line 9 increasing the flow through the anode to improve flow distribution.

Pressure difference sensor 6 detects the cross cell pressure differential. Controller 6A operates valve 7 in the anode discharge line to maintain the desired pressure differential.

During normal operation anode exhaust fuel and cathode exhaust air are supplied to a reformer burner while firing them in the reformer. At this time, pressures of the anode exhaust fuel and cathode exhaust air become equal in a burner combustion chamber. The number of devices installed in the cathode exhaust air line is normally larger than in the anode exhaust fuel line (for example, heat exchanger in the air line).

Therefore, a pressure loss in the cathode exhaust air line becomes larger than that in the anode exhaust fuel line and there is a possibility that an intolerably large cathode to anode over-pressure may be caused in steady state or transient operation.

Therefore, a control valve 7 in the anode exhaust fuel line maintains a cell cross differential pressure within an allowable range. In a normal operation state, there is always a gas flow in the anode exhaust fuel side. With the pressure in each of the cathode and anode flow lines pegged at the burner this control

valve may be modulated to affect the anode side pressure level. This pressure difference across the control valve is controlled to maintain the desired cell cross differential pressure.

5        On the other hand, in a process for plant shutdown, the air flow control valve is closed while purging the cathode with a nitrogen flow 18. At the same time, the fuel flow control valve 5 is also closed, resulting in no fuel being supplied to the  
10 burner through the anode.

         However, with such a fuel cell power plant, no gas flows in the anode exit line when the cathode exhaust gas line is purged with nitrogen, and with the fuel supply valve shut off. Therefore, no suitable pressure  
15 difference is created across the valve no matter how the cell cross differential pressure control valve is controlled. Consequently, the function of cell cross differential pressure adjustment is no longer effective. As a result, an excess cell cross  
20 differential pressure causes deterioration of cell performance and fracture in part, as a fatal problem.

         In such a flow scheme where the cell cross differential pressure control valve comprises only a single control valve, there is a problem when cell  
25 cross differential pressure control becomes impossible on failure of the control valve either fully open or fully closed.

#### Summary of the Invention

         In order to achieve the object described above  
30 according to the present invention, a cell cross differential pressure control valve is installed in the line between the anode exit and the branch point of the

anode recycle line. This anode recycle is used to improve fuel distribution among the anodes. When purging nitrogen begins, the recycle blower is operated to create a gas flow in the anode recycle line. Thus, with this location of the control valve a suitable differential pressure is produced across the valve and the pressure may be controlled. In the result, cell cross differential pressure control is accomplished even during purge operation.

The control valve arrangement which maintains the pressure differential across the cell include an always open minimum flow path and preferably two parallel valves operating at the mid-position. The minimum opening limits pressure escalation if the valves fail closed. The dual valves provide continued operability in the event of failure of one of the valves.

#### Brief Description of the Drawings

Figure 1 is the process flow diagram for showing an embodiment according to the present invention'

Figure 2 is the process flow diagram for showing another embodiment of the invention;

Figure 3 shows the process flow diagram for a conventional fuel cell power plant known in the prior art.

#### Description of the Preferred Embodiment

Figure 1 shows an example of preferred flow scheme for a fuel cell power plant according to the invention. The same reference numerals are used for the same portions as Fig. 3, while omitting detailed descriptions.

With this embodiment, valve complex 20, similar to cell cross pressure control valve 7, is installed in an anode recycle loop by locating it between the anode and the takeoff for the recirculating line 9.

5        When the plant is on load operation, fuel and air are supplied to the anode and the cathode by a fuel flow control valve 5 and an air flow control valve 11, respectively. Gases, leaving the anode and the cathode, are supplied separately to a burner 15 and used as a heat source for the fuel reforming reaction. It is the same operation as the flow scheme of a fuel cell plant shown in Fig. 4 in that the signal of a differential pressure transmitter 6 is transferred to a controller 6A from which a suitable valve opening  
10        signal is given to the cell cross pressure control valve 7.  
15

When the plant is shutdown, and a nitrogen purge flow is to be passed through the cathode, the anode recirculation blower 8 is operated to produce a gas  
20        flow in the anode recycle line. Since the cell cross pressure control valve complex 20 is installed in the recirculation loop, the pressure level in the anode above the burner pressure may be modulated. An anode-to-cathode pressure differential can therefore be  
25        controlled.

As a result, the occurrence of excess cell cross differential pressure onto the cell itself can be effectively prevented, while enabling purging during shut down without cell performance deterioration or  
30        fracture.

The valve complex 20 is comprised of an orifice 22 in parallel with control valves 24 and 26. In the prior art arrangement there was always the possibility

that the control valve would malfunction in the closed position resulting in a rapid escalation of the anode pressure. With a fixed opening in the line provided by the orifice, the pressure escalation will be limited because of the flow and pressure drop through the orifice. Since the flows through the anode line and the cathode line are normally in a substantially constant ratio, it might theoretically be possible to size the orifice to maintain the pressure drop in both lines. This, however, is not practical since the flows are not always completely proportional and transient operation must be considered. If the orifice were sized at the limit, there would be no way to increase the pressure drop in that line. Since, however, a higher than normal pressure difference may be accepted across the fuel cell electrolyte membrane for a short period of time the orifice may be selected based on the higher differential. This will not permit continued operation in the event of a valve closure, but it will avoid immediate damage, providing time to trip the plant or take other remedial action.

This use of an orifice in parallel with control valves has utility even with the prior art anode recirculation location. It's use in combination with the new anode recirculation location provides a further advantage, however. Should the orifice be selected such that at some operating condition insufficient pressure drop exists across the orifice, the recirculation line may be activated providing increased pressure drop across the orifice.

Valves 24 and 26 located in parallel with the orifice are the valves which are modulated by controller 6A to maintain the cross cell pressure



difference. These are selected to operate in the mid range and preferably selected so that if either valve is full open or full closed, the other valve can continue to control the pressure within the desired  
5 range. Again, further control is possible by electing whether or not to operate blower 86 and effect recycle with flow passing through the control valve complex.

Further flexibility is achieved in the embodiment illustrated in Figure 2. In the valve complex 20 the  
10 multiposition valve 28 is substituted for orifice 22. This valve preferably is not fully closable, but may be set at any one of a plurality of openings. This is the equivalent of the orifice, except that the orifice may be changed by selecting the valve position. This  
15 permits the particular orifice selection to be more closely adjusted to the operating load condition of the plant by manually or automatically selecting various equivalent orifice sizes as a function of the load.

Accordingly, the cell cross pressure control of  
20 the prior art is achieved without danger of immediate damage in the event of a closed valve failure of the control valve. Furthermore, the ability to maintain pressure differential across the electrolyte membrane is achieved during nitrogen purging with the plant shut  
25 down.

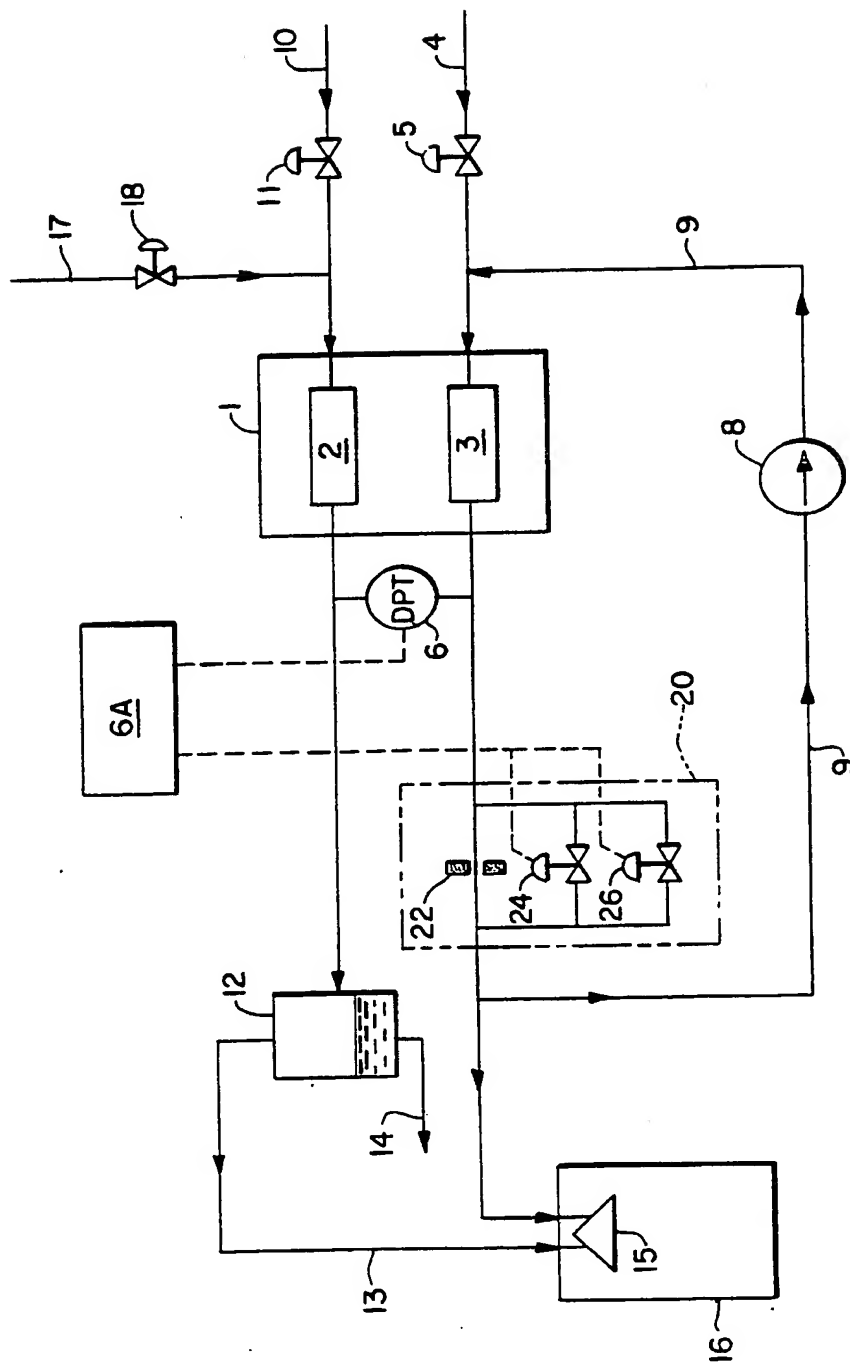
## Claims

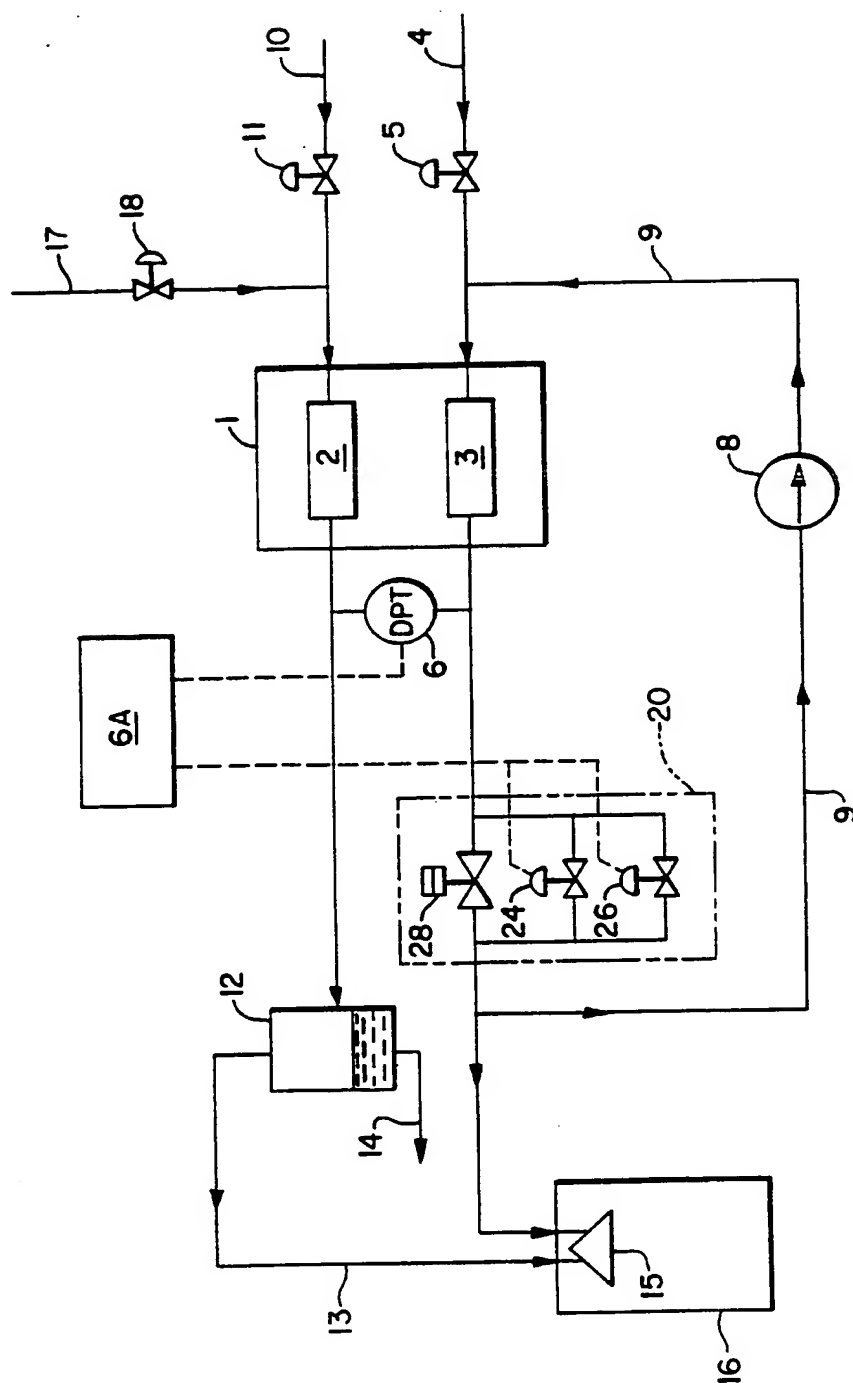
1. In a fuel cell power plant including a fuel cell stack containing fuel cells, each having an anode and a cathode, an anode recirculation line for returning at least a part of anode exhaust gas via an anode recycle blower to the anode inlet, a differential pressure transmitter for measuring a differential pressure between the anode and the cathode, a cell cross pressure control valve complex, and a controller for controlling a degree of opening of said cell cross pressure control valve according to a measured value of said differential pressure transmitter, the fuel cell power plant characterized in that said cell cross pressure control valve complex is installed in the line between the anode outlet and a branch point of said anode recirculation line from the anode outlet line.
2. A fuel cell power plant as in claim 1, wherein said cell cross pressure control valve comprises a control valve and either an orifice or a fixed opening throttle valve, and said control valve is in parallel with said orifice or throttle valve.
3. A fuel cell as in claim 1 comprising at least two control valves in parallel with said orifice or throttle valve.
4. A fuel cell power plant as in claim 2, wherein said fixed opening throttle valve is adjustable to at least two different openings.

5. In a fuel cell power plant including a fuel cell stack containing fuel cells, each having an anode and a cathode, an anode recirculation line for returning at least a part of anode exhaust gas via an anode recycle blower to the anode inlet, a differential pressure transmitter for measuring a differential pressure between the anode and the cathode, a cell cross pressure control valve complex, and a controller for controlling a degree of opening of said cell cross pressure control valve according to a measured value of said differential pressure transmitter, the fuel cell power plant characterized in that said cell cross pressure control valve complex comprises a control valve and either an orifice or a fixed opening throttle valve, and said control valve is in parallel with said orifice or throttle valve.

6. A fuel cell as in claim 5 comprising at least two control valves in parallel with said orifice or throttle valve.

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FIG. 1

FIG. 2

3 / 3

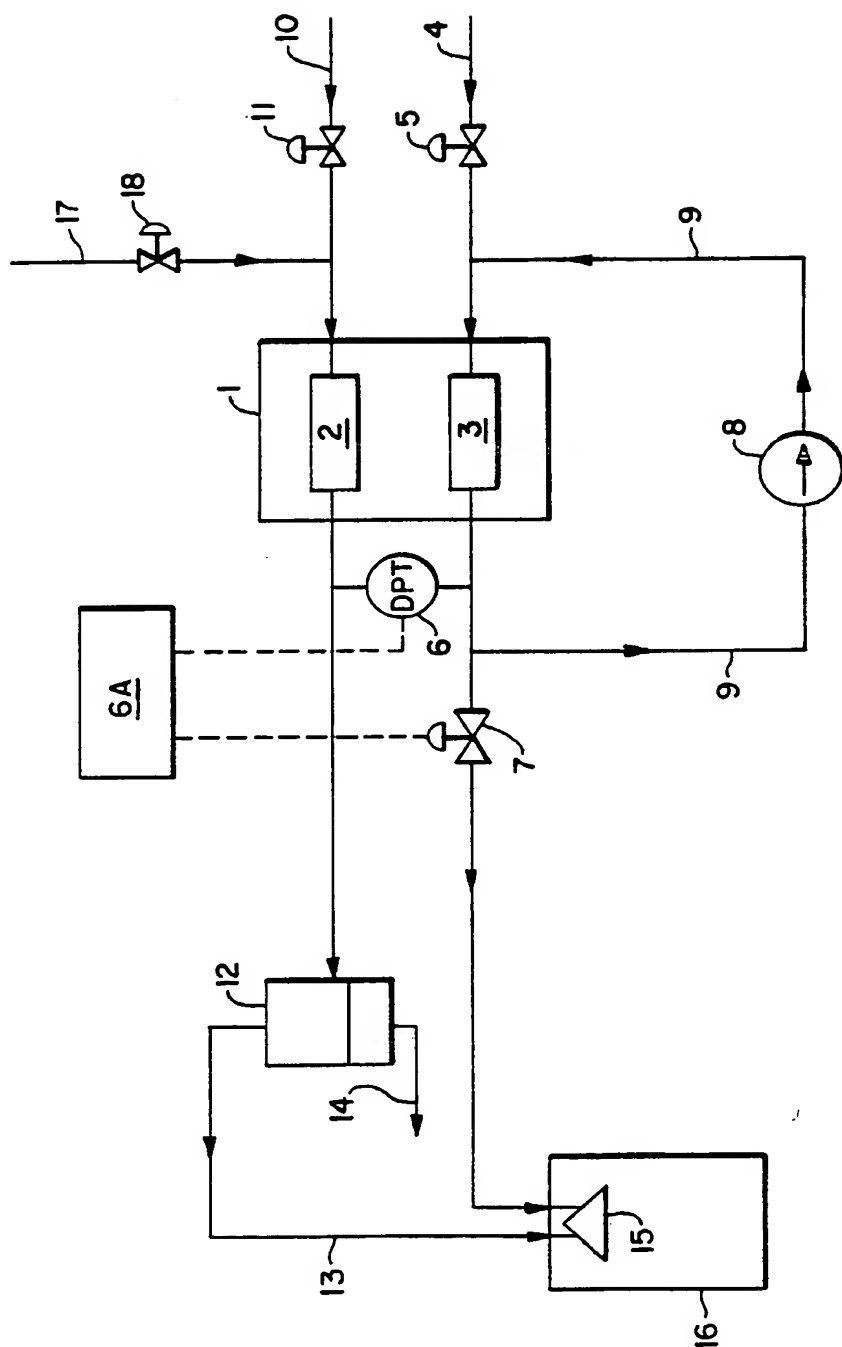


FIG. 3  
PRIOR ART

# INTERNATIONAL SEARCH REPORT

International Application No. PCT/US91/03279

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>6</sup> According to International Patent Classification (IPC) or to both National Classification and IPC <div style="margin-left: 40px;">           INT. CL. 5 H01M 8/04            US. CL. 429/17         </div>														
<b>II. FIELDS SEARCHED</b> <div style="text-align: right; margin-right: 100px;">Minimum Documentation Searched <sup>7</sup></div> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 20%; padding: 5px;">Classification System</td> <td style="padding: 5px;">Classification Symbols</td> </tr> <tr> <td style="padding: 5px;">US CL</td> <td style="padding: 5px;">429/17, 25</td> </tr> </table> <div style="text-align: center; margin-top: 10px;"> <small>Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup></small> </div>			Classification System	Classification Symbols	US CL	429/17, 25								
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US CL	429/17, 25													
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>9</sup></b> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 10%; padding: 5px;">Category <sup>10</sup></th> <th style="width: 60%; padding: 5px;">Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup></th> <th style="width: 30%; padding: 5px;">Relevant to Claim No. <sup>13</sup></th> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">Y</td> <td style="padding: 5px;">JP, A, 60-158,559 (TAGUMA) 19 AUGUST 1985 See the Abstract and the drawings.</td> <td style="text-align: center; vertical-align: top; padding: 5px;">1</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">JP, A, 60-165,063 (SUGITANI) 28 AUGUST 1985 See the Abstract</td> <td style="text-align: center; vertical-align: top; padding: 5px;">1-6</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">US, A, 4,769,297 (REISER ET AL) 06 SEPTEMBER 1988 See the Abstract and figure 1.</td> <td style="text-align: center; vertical-align: top; padding: 5px;">1-6</td> </tr> </table>			Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>	Y	JP, A, 60-158,559 (TAGUMA) 19 AUGUST 1985 See the Abstract and the drawings.	1	A	JP, A, 60-165,063 (SUGITANI) 28 AUGUST 1985 See the Abstract	1-6	A	US, A, 4,769,297 (REISER ET AL) 06 SEPTEMBER 1988 See the Abstract and figure 1.	1-6
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<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p><small>* Special categories of cited documents: <sup>10</sup></small></p> <p><small>"A" document defining the general state of the art which is not considered to be of particular relevance</small></p> <p><small>"E" earlier document but published on or after the international filing date</small></p> <p><small>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</small></p> <p><small>"O" document referring to an oral disclosure, use, exhibition or other means</small></p> <p><small>"P" document published prior to the international filing date but later than the priority date claimed</small></p> </div> <div style="width: 50%;"> <p><small>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</small></p> <p><small>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</small></p> <p><small>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</small></p> <p><small>"&amp;" document member of the same patent family</small></p> </div> </div>														
<b>IV. CERTIFICATION</b> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; padding: 5px;">           Date of the Actual Completion of the International Search  <div style="margin-left: 40px;">11 JULY 1991</div> </td> <td style="width: 50%; padding: 5px;">           Date of Mailing of this International Search Report  <div style="margin-left: 40px; font-size: 1.2em;">13 AUG. 1991</div> </td> </tr> <tr> <td style="padding: 5px;">           International Searching Authority  <div style="margin-left: 40px;">ISA/US</div> </td> <td style="padding: 5px;">           Signature of Authorized Officer  <div style="text-align: center;">              STEPHEN J. KALAFUT           </div> </td> </tr> </table>			Date of the Actual Completion of the International Search <div style="margin-left: 40px;">11 JULY 1991</div>	Date of Mailing of this International Search Report <div style="margin-left: 40px; font-size: 1.2em;">13 AUG. 1991</div>	International Searching Authority <div style="margin-left: 40px;">ISA/US</div>	Signature of Authorized Officer <div style="text-align: center;">              STEPHEN J. KALAFUT           </div>								
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